

High-Density Interconnects for 2-Dimensional VCSEL Arrays Suitable for Mass Scale Production

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- **Problem:**

 - Increasing # of Optical Channels/ Circuit Card*

 - Increasing # of Transmitters/ per Board*

 - Increased Allocation of Board Space*

- **Solution: Transmitters w/ Increased Channel Density**

 - 2D VCSEL's more cost & space effective per channel

- **Issue: Cost Effective Interconnects for High Density Arrays**

- **Scaleable Polymer Waveguide Fabrication Process**
- **GuideLink™ Polymer Waveguide Properties**
- **Waveguide Design Optimization for VCSEL Interconnects**
- **Waveguide-VCSEL Coupling Options**
- **Fabrication of Connectorized Linear and 2D Arrays**
- **Summary**

GuideLink™ Polymer Waveguide System

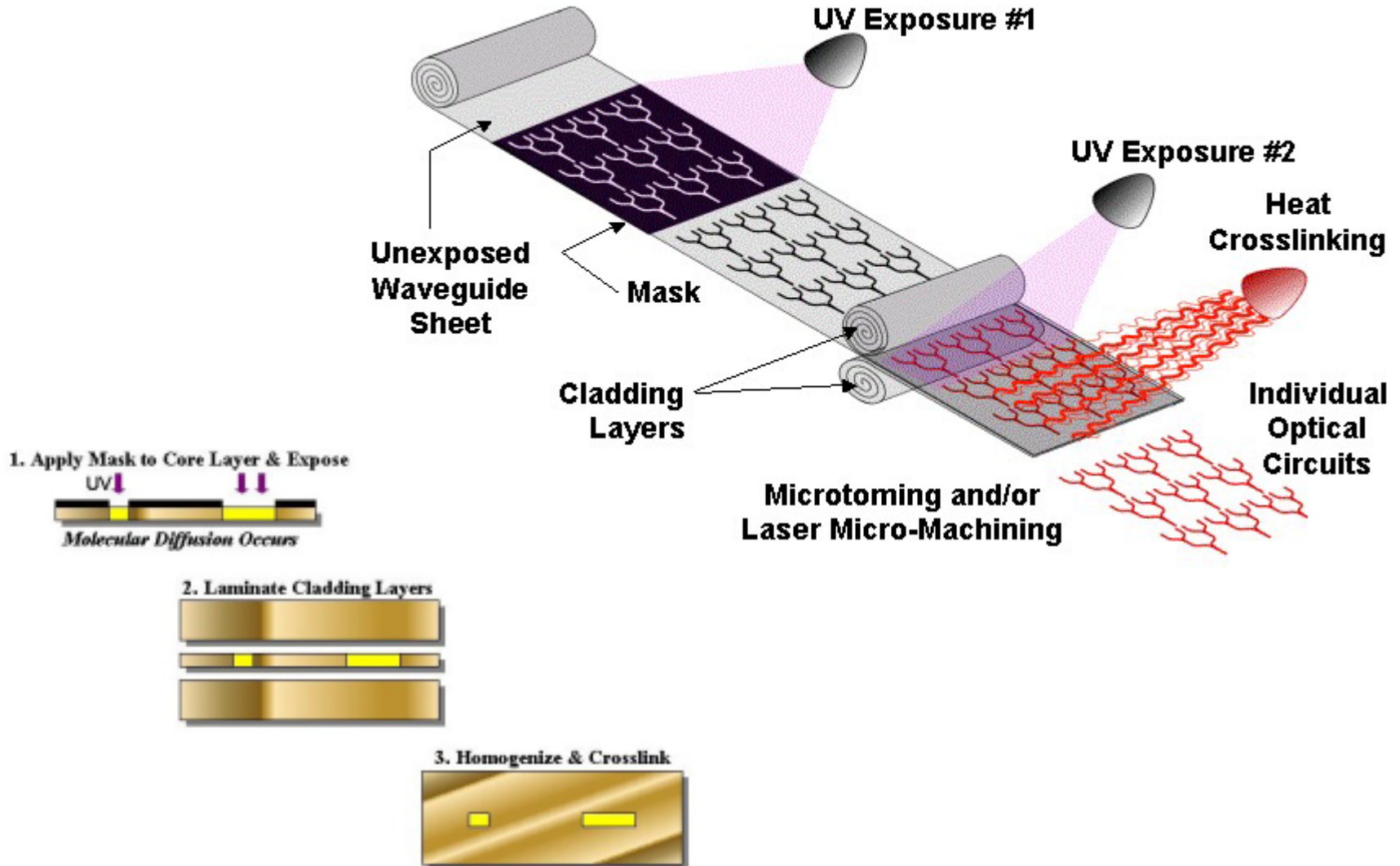
Driving optical integration



- A proprietary formulation of a monomer/polymer mixture is web coated onto a mylar host to form rolls of film
- Film rolls are currently 13” wide and ~500 feet long... in large scale production, rolls can be 36” or 72” wide and in excess of 1000 feet long
- Uniformity of the coating thickness is held to +/- 1 μm across entire roll

GuideLink™ Polymer Waveguide Formation

Driving optical integration

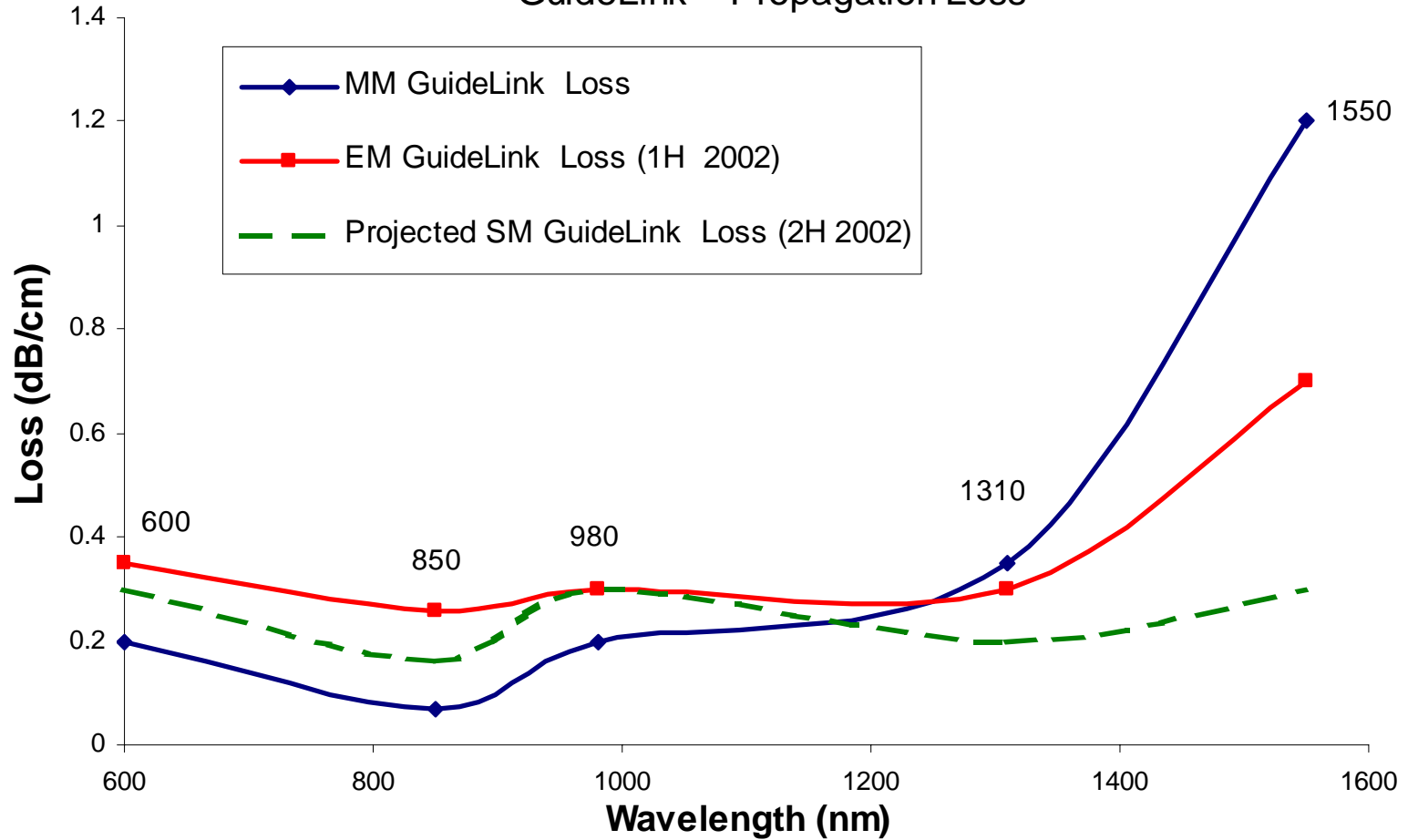


- **Square waveguide profile with customizable core size.**
 - Waveguide controlled by varying film thickness
 - 6, 35, and 50 um waveguide heights standard.
- **Customizable numerical aperture.**
 - NA's available from 0.10 to 0.32.
 - Standard index profile is step index
- **Mechanical flexibility**
- **Mask-defined waveguide routing** (*for pitch transitions, tapers, bends, etc.,*)
- **Stackability**

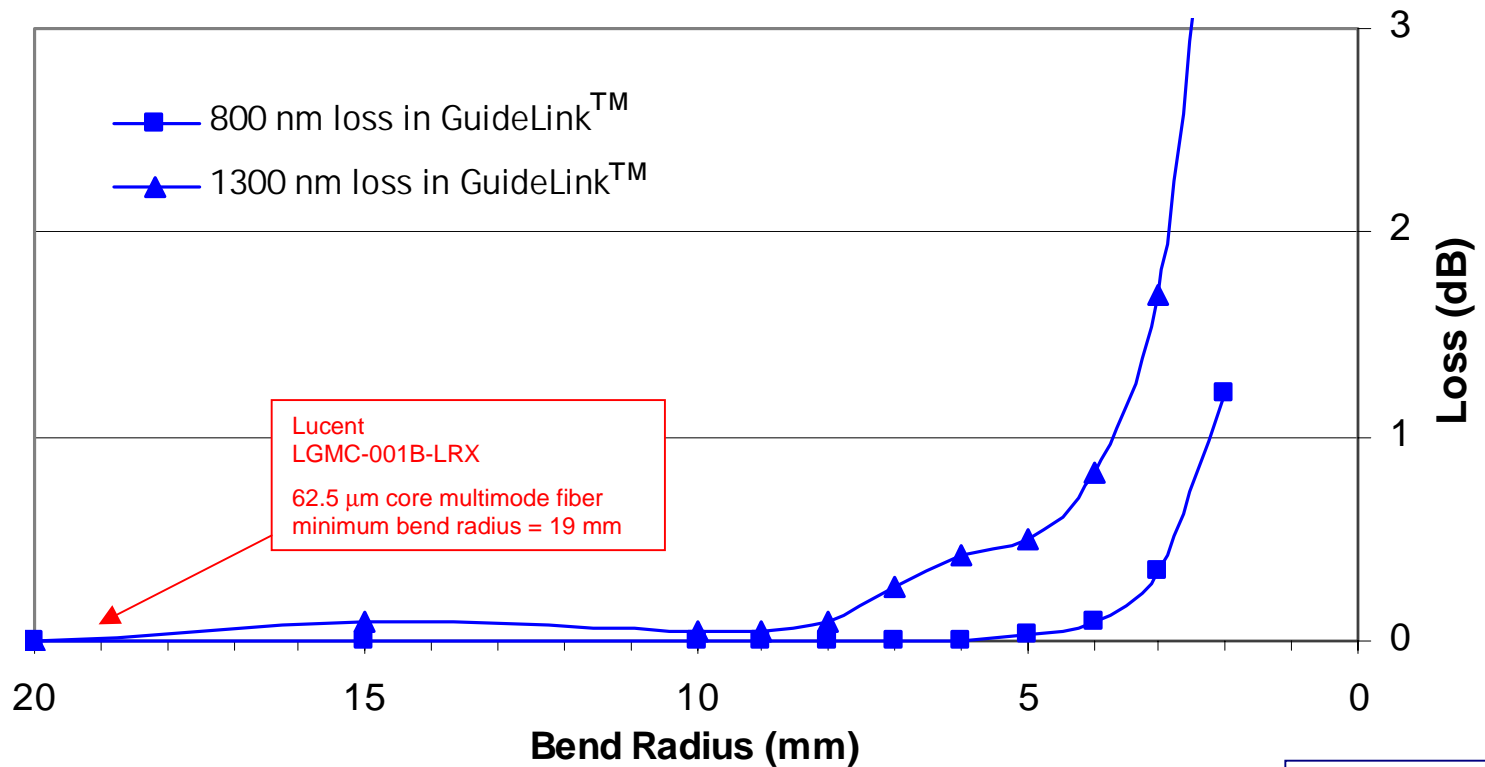
Propagation Loss

Driving optical integration

GuideLink™ Propagation Loss



Comparison of Out-of-Plane Bend Loss (multimode)



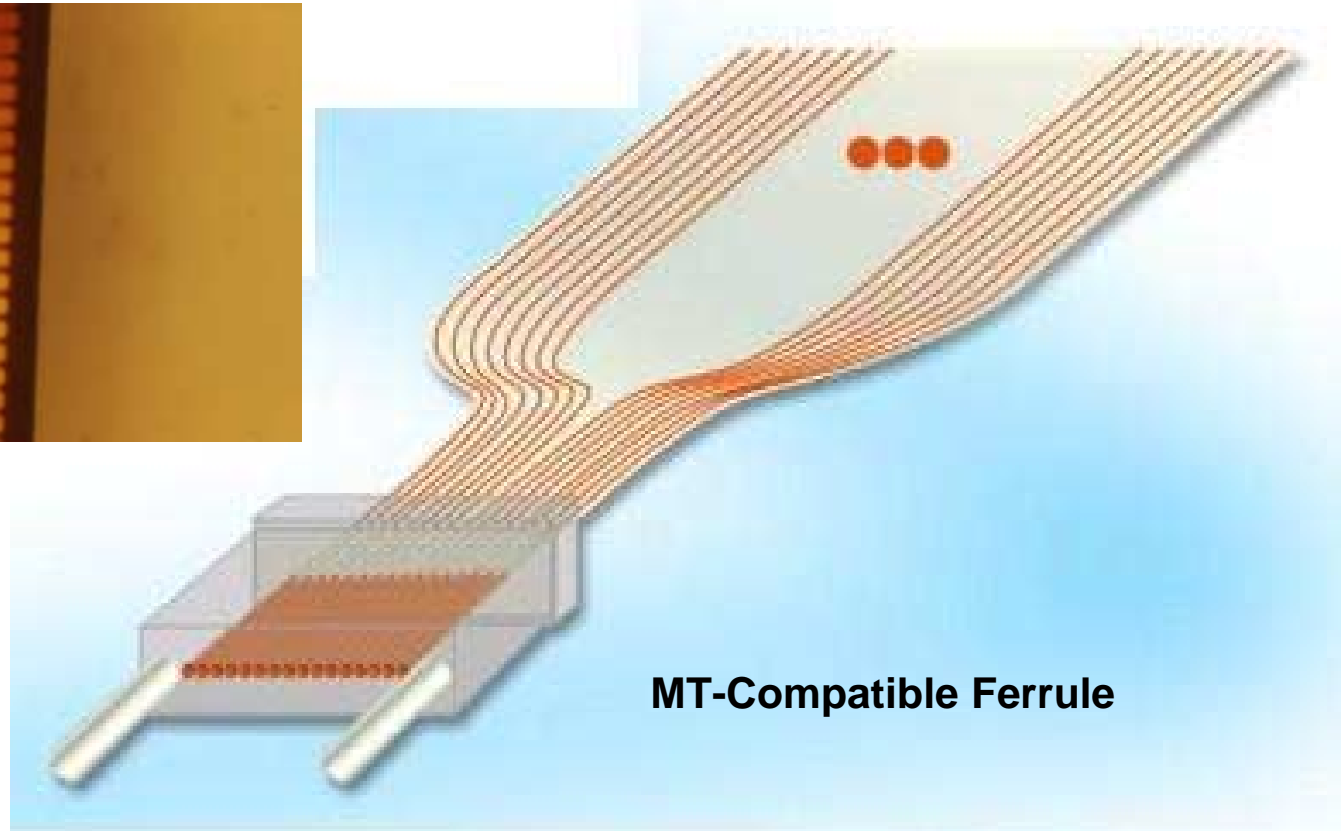
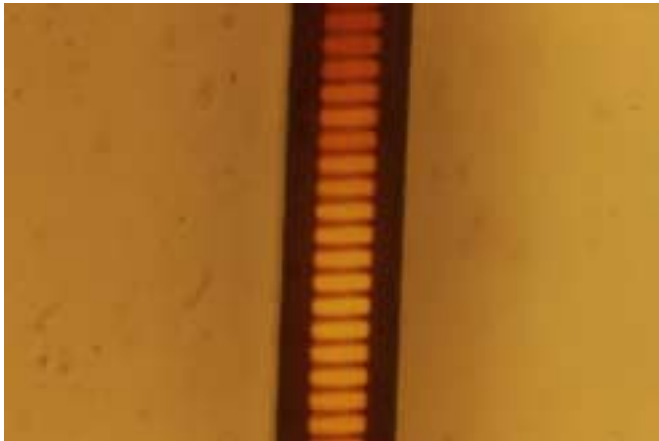
50 μm square guides

High Density Pitch Transition Devices

Driving optical integration

**4-Micron Gap Between
20um x 45um Guides**

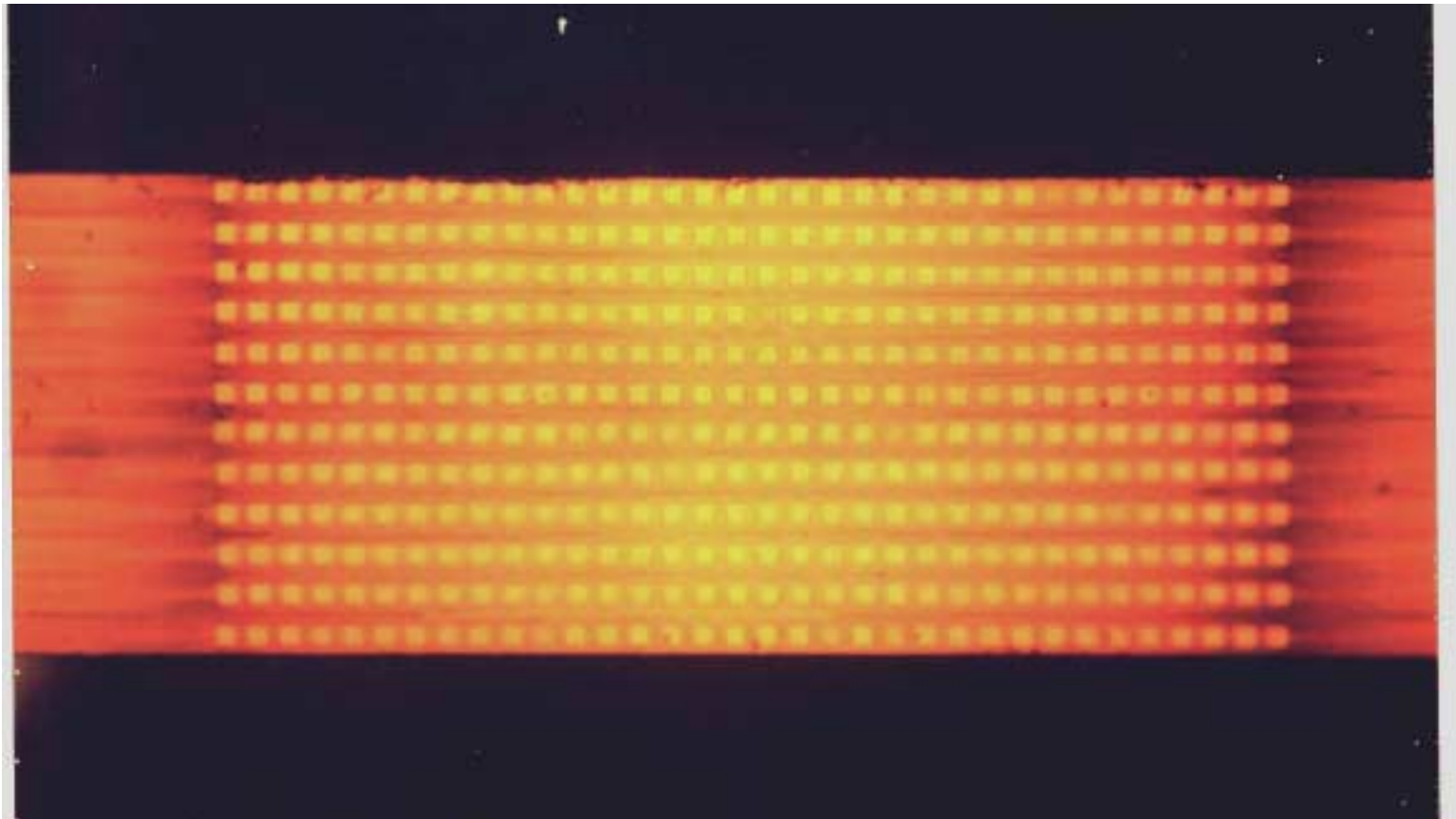
Pitch Transitioned to Larger/Smaller Spacing



Waveguide Stacking for 2-D Applications

Driving optical integration

12 Waveguide Layers with 34 Guides per Layer



- **Insertion Loss**
 - **Propagation Loss** (*bends, NA, length, λ , etc*)
 - **Coupling Loss**
 - NA of VCSEL, Fiber, or Detector
 - Active Area of VCSEL or Detector
 - Axial Displacement from VCSEL or Detector

- **Package Constraints**
 - **Package Size** (height & length)
 - **Device Pitch**
 - **VCSEL Orientation**

Coupling Considerations: Mode Field and Aperture Effects

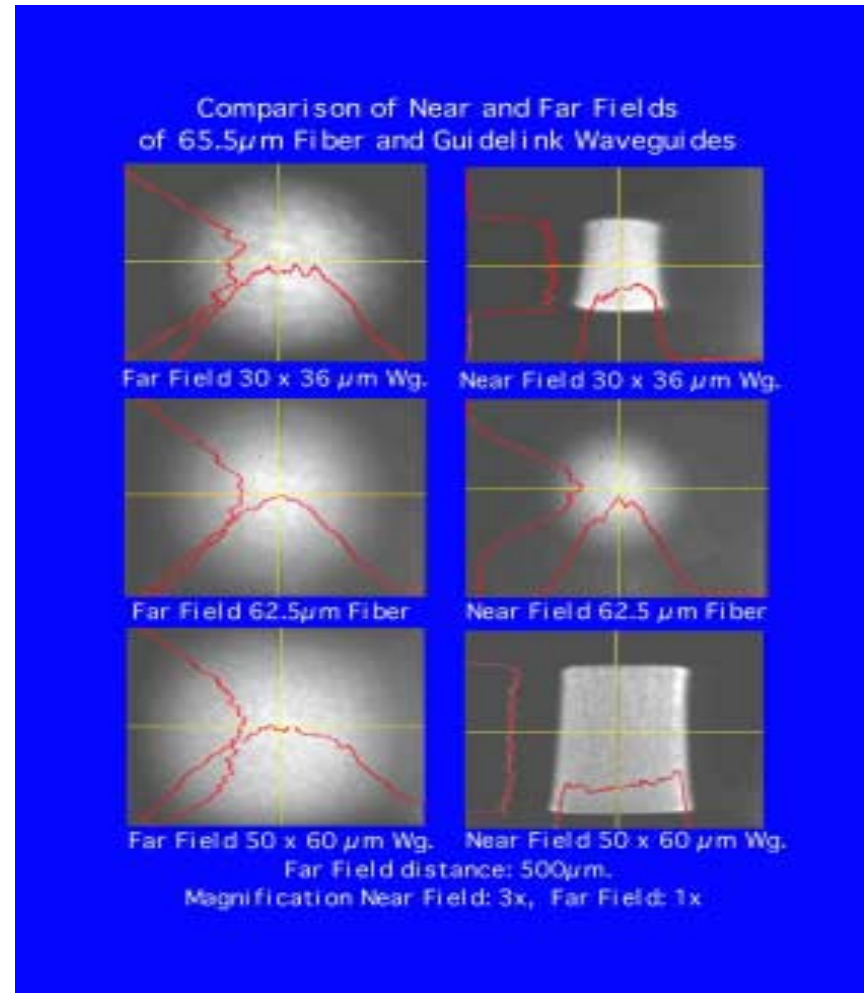
Driving optical integration

VCSEL → Waveguide → Fiber:

- Progressively larger aperture:
10 μm → 30 μm → 62.5 μm
- Progressively larger NA:
0.2 (VCSEL) → 0.24 (WG) → 0.27 (Fiber)

Fiber → Waveguide → Detector:

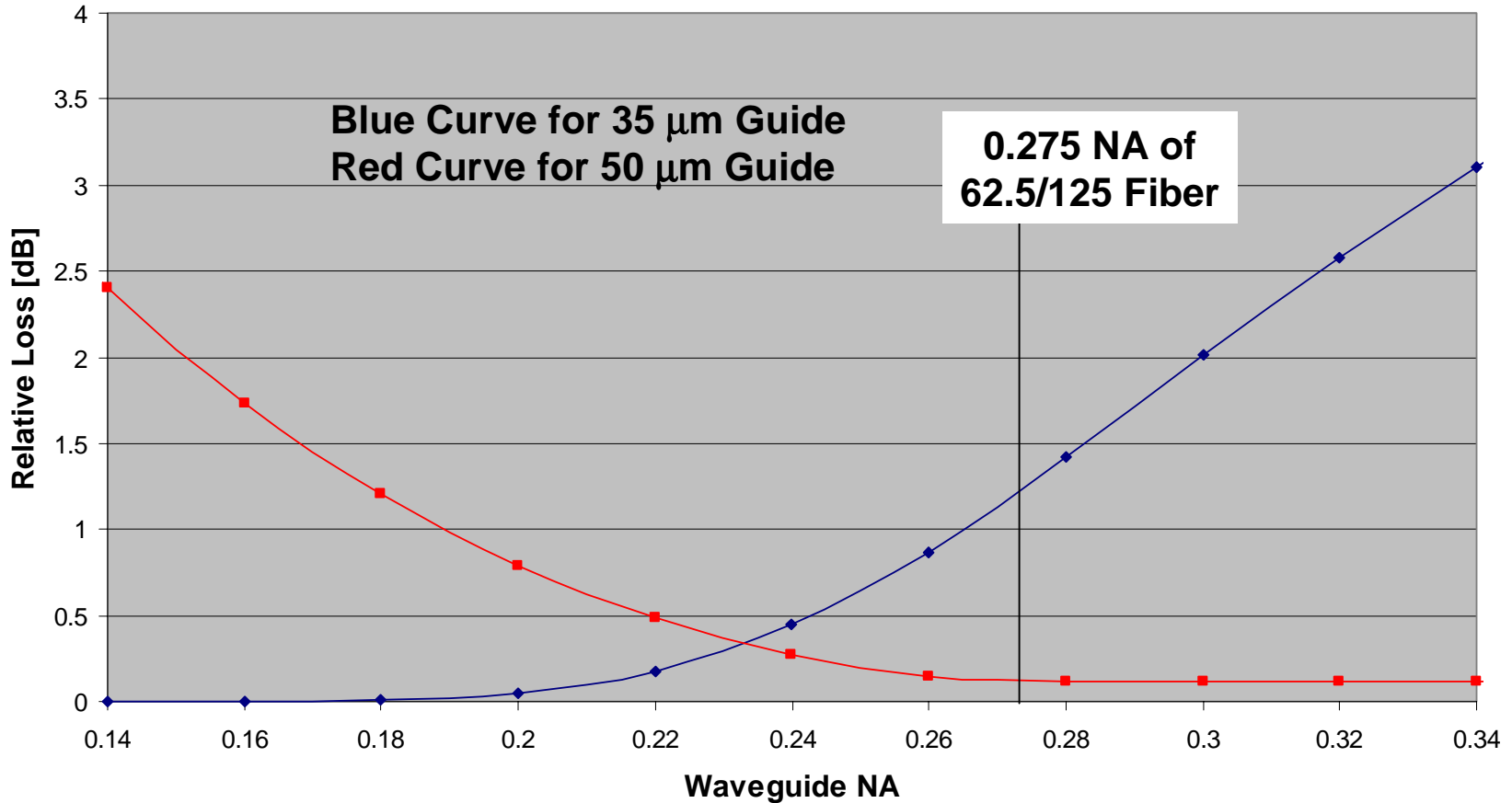
- Maintain Aperture:
62.5 μm → 50 x 60 μm
- Progressively larger NA:
0.27 (Fiber) → 0.32 (WG) → detector



Coupling Considerations: Customizing Tx and Rx Optical Links

Driving optical integration

Coupling Loss vs. NA (Blue - WG to Fiber, Red- Fiber to WG)



“Bending Photons” for Low-Profile VCSEL Interconnects

Driving optical integration

Low-Cost 1x12 VCSEL
Transmitters Require Turning
Photons 90° From VCSEL
Surface to Fiber Output.

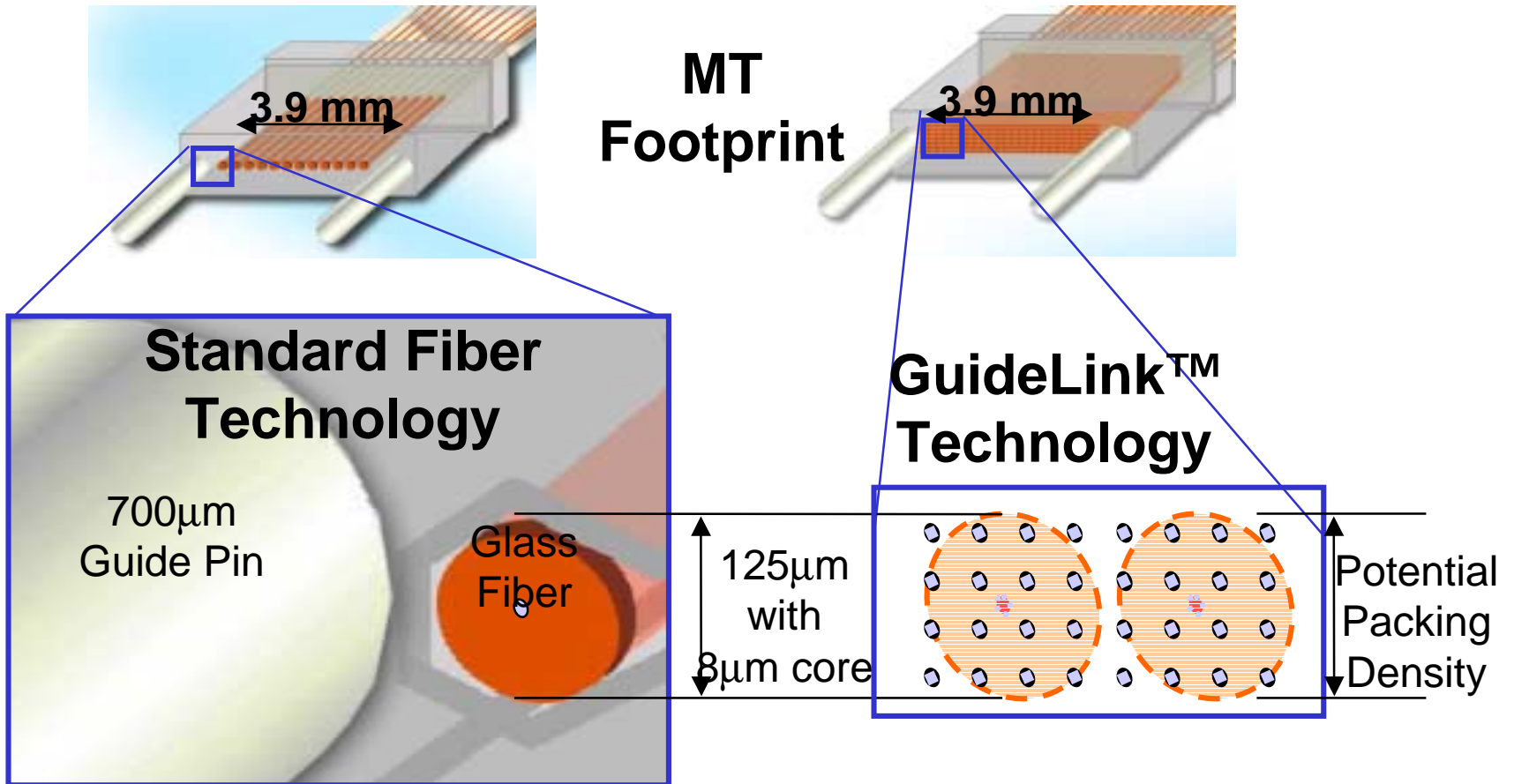
- 45° Mirror on Waveguide End-Face
- Thermo-Formed 90° Bend in Polymer for End-Fire Coupling



- **Options available for coupling in/out of waveguides:**
 - Passively or actively aligned fiber pigtail.
 - End-fire or mirror coupling directly to active device.
 - Lens-assisted coupling
- **Direct connectorization of waveguide in high density format**
2-D arrays up to 8 x 75 in standard MT format.
Standard or custom configurations available.

GuideLink™ High Density Interconnects

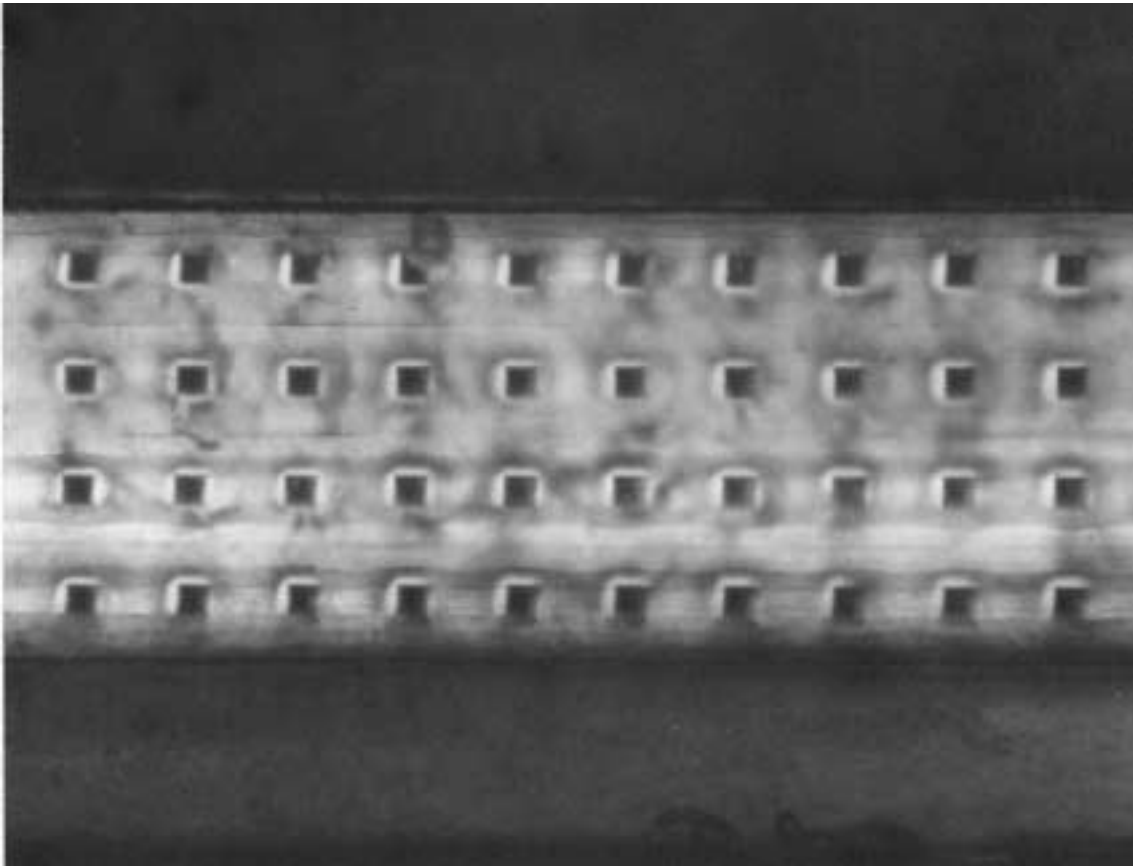
Driving optical integration



- **High-Density Linear Arrays**
 - Pitch range: 40um \rightarrow > 500um
 - Transition pitch from VCSEL to desired output interface (ex. 100um \rightarrow 250um)
 - Array registered to MT guide pins for easy alignment
- **Stacked Arrays**
 - Waveguide layers can be directly stacked or placed at user-defined locations relative to MT ferrule alignment pins
 - Registration of guides is well preserved inside array and to MT pins
 - Individual waveguide layers can be separated for easier routing and interfacing
- **Overcoated Polymer Provides Robust MT Interface**
 - Solvent resistant
 - Scratch and impact resistant for repeated mating

Registration of Waveguides In Array

Driving optical integration

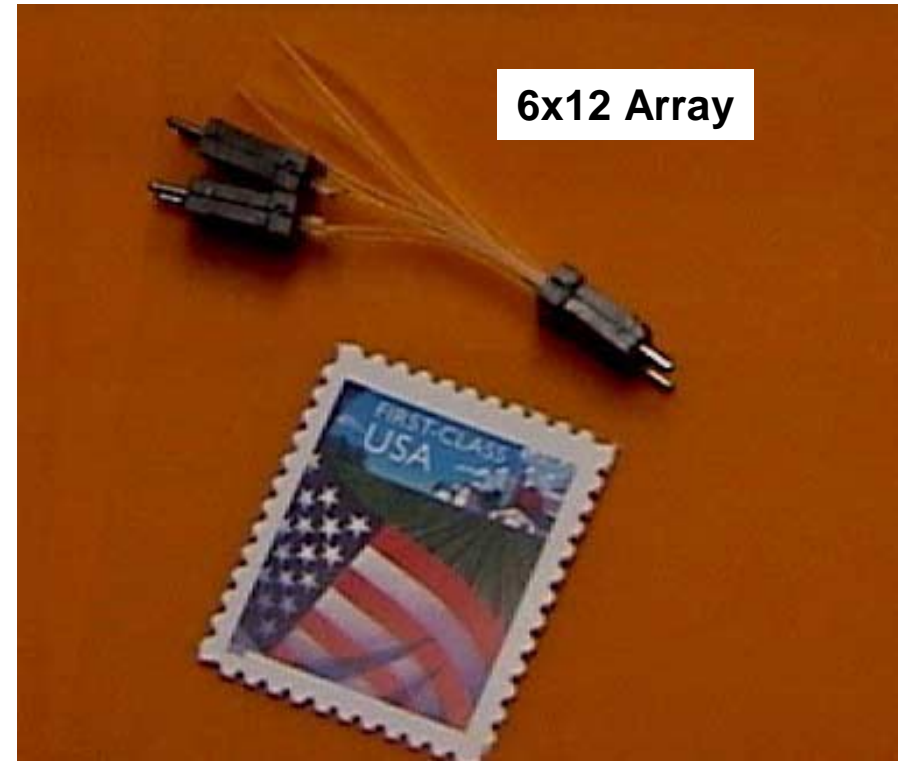
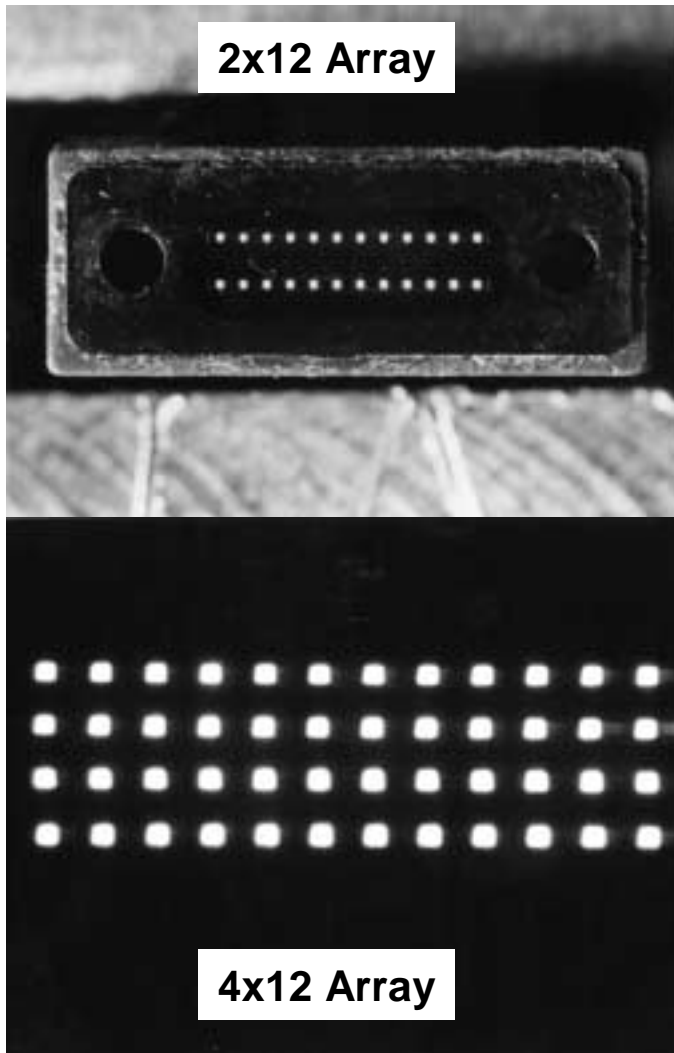


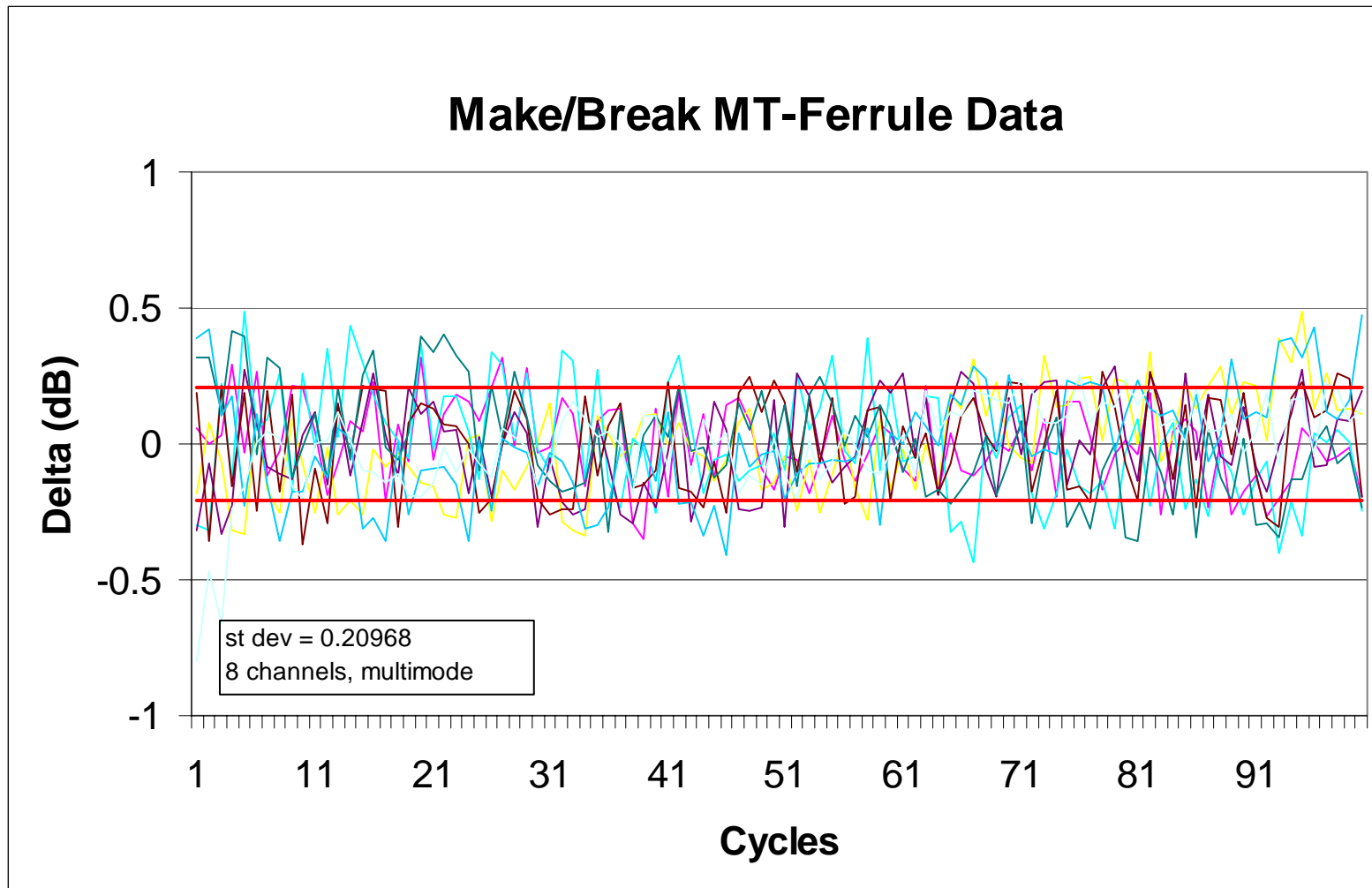
**Waveguide Registration
Measured with Template
Overlay**

**Shadowing is Caused
By Difference in Focal
Planes Between
Waveguide and
Template**

**Registration Accuracy
Shown is Approx.
 ± 2 microns**

Stacked Array Examples





- **Scalable Polymer Film-Based Fabrication Process**
- **Versatile Waveguide Properties:**
 - Multimode Waveguides, 30-50 microns Square with Step Index
 - Flexibility for Low-Loss, Tight Bending
- **Waveguide Design Optimization for VCSEL Interconnects**
 - Polymer NA 0.22-0.32 for Optimal Directional Performance
 - Guide Dimensions & Pitch Photolithographically Defined
- **Variety of Low-Profile High Density Waveguide-VCSEL Coupling Options**
- **Fabrication of Connectorized Linear and 2D Arrays**
 - Minimum Spacing Between Guides (Same Layer) ~10 microns
 - Minimum Spacing Between Guides (Adjacent Layers) ~ 30 microns
 - Up to 8-Layers Stacked in Standard MT Ferrule
 - Waveguide Registration Accuracy $< \pm 2$ microns